C Primer

A crushing crash course / revision on C

Overview

- The C Programming Language
  - Brief History
  - Programming Model
- Major C Programming Constructs
  - Control Statements
  - Data Types
    - Pointers
  - Function
- Built-in C Libraries
  - Input/Output
  - String Manipulation
- Compilation Process
  - Preprocessing Macro

C Programming Language: Brief History

- Designed by Dennis Ritchie in 1972

- First book that defines a standard C:
  - Brian Kernighan and Dennis Ritchie in 1978
  - Known as the ***K & R C***

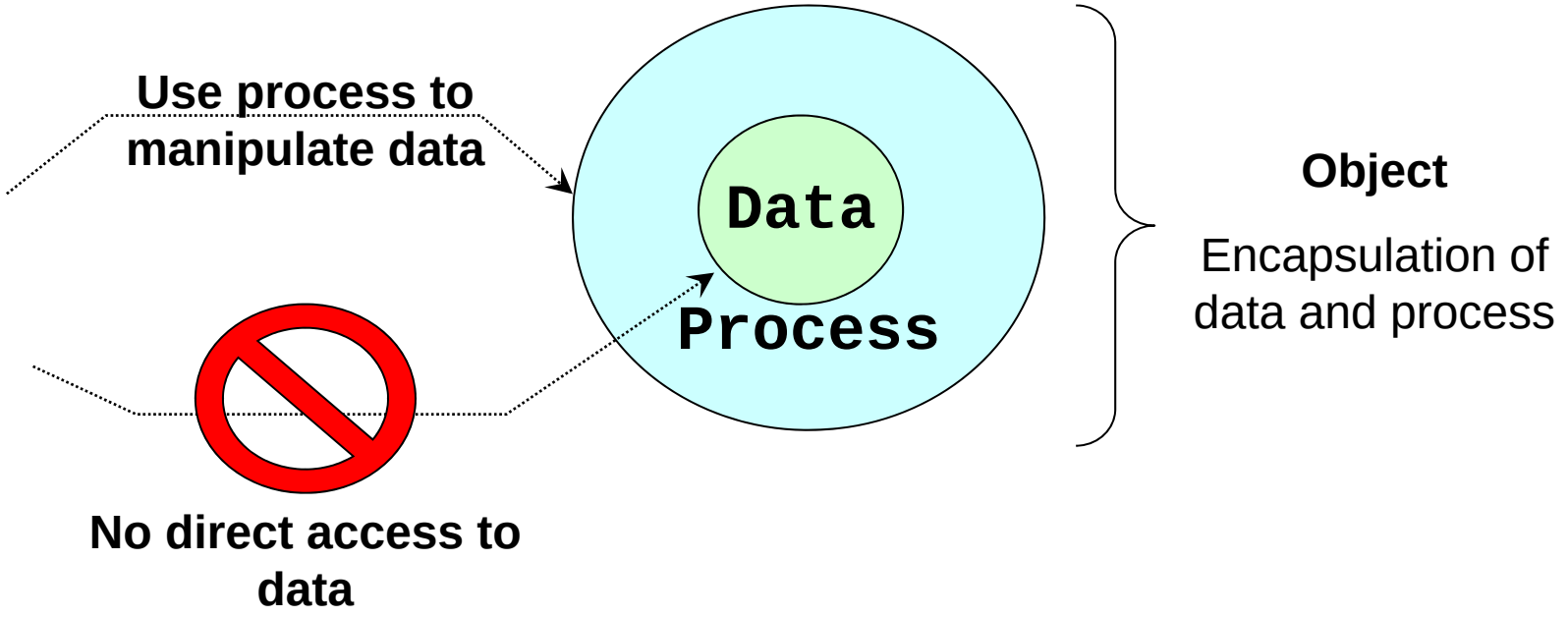
- Standardized in 1989 by ANSI
  - Known as the ***ANSI C***
  - Coverage base on this version

Programming Model

- C is designed with a ***Minimalist*** approach
  - Provide only the essential constructs
  - "Assume the programmers know what they are doing" – K & R
    - Minimal or No intervention from the compiler to ensure program correctness

- C uses ***Procedural*** programming model
  - Java and C++ uses ***Object-Oriented*** model
  - Less overhead in writing code
  - Harder to organize data and process

Object Oriented Programming Model

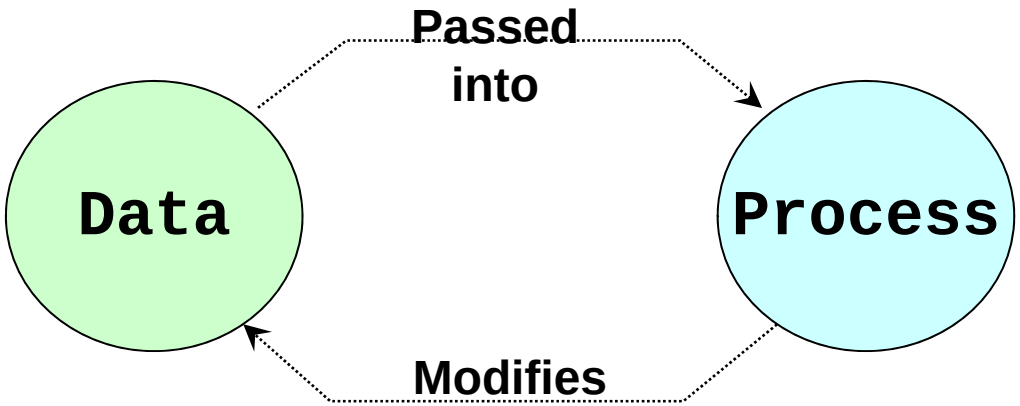



```
class Counter
{
    private int _i;
    ...
    public void increment() { _i++ };
    ...
}
```

Data

Process

Procedural Programming Model




```
void increment( int* a)
{
    (*a)++;
}

int i;

increment( &i );
```

Process

Data

Data passed into a process

Procedural Programming Model

- A program in this model consists of:
  - Data:
    - "Naked": directly accessible to everyone
    - Still possible to group data in meaningful packages through ***structure*** (more later)
  - Process:
    - Function:
      - Receive data and perform manipulation
      - "Transient": Do not remember information (mostly)
- It is the programmer responsibility to:
  - Introduce meaningful organization
  - Separate process and data into logical groups

Hello World….. Again

- A simple side-by-side comparison between Java and C:

```
public class HelloWorld {

public static void main( String args[] ) {
    System.out.println( "Hello World!" );
}
}
```

Source File

`HelloWorld.java`

```
#include <stdio.h>

int main( )
{
    printf( "Hello World!" );
    return 0;
}
```

Header File

Function Call

Source File

No restriction. Can use any file name with suffix "**.c**"

e.g. **`hello.c`** , **`program1.c`** etc

C Programming Construct

Selection Statements

```
if (a > b) {
    ...
} else {
    ...
}
```

- `if-else` statement
- Valid conditions:
  - Comparison
  - Integer values (0 = false, others = true)

```
switch (a) {
    case 1:
        ...
        break;
    case 2:
    case 3:
        ...
    default:
}
```

- `switch-case` statement
- Variables in switch( ) must be integer type (or can be converted to integer)
- `break` : stop the fall through execution
- `default` : catch all unmatched cases

Repetition Statements

```
while (a > b) {
    ... //body
}
```

```
do {
    ... //body
} while (a > b);
```

- Valid conditions:
  - Comparison
  - Integer values (0 = false, others = true)
- `while` : check condition before executing body
- `do-while`: execute body before condition checking

```
for (A; B; C) {
    ... //body
}
```

- `A` : initialization (e.g. `i = 0`)
- `B` : condition (e.g. `i < 10`)
- `C` : update (e.g. `i++`)
- Any of the above can be empty
- Execution order:
  - `A, B, body, C, B, body, C …`

Pitfall for Java Programmer

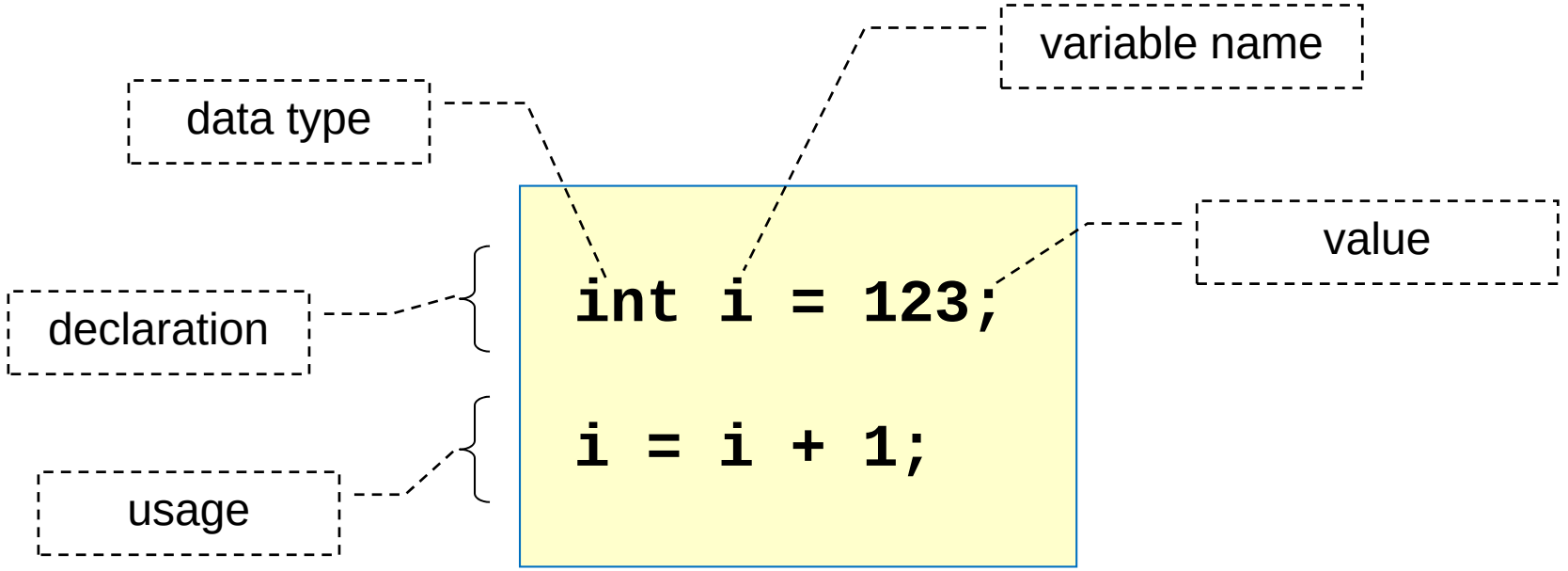
- Integer values is acceptable as condition in C
  - Can produce subtle logical bug!
- Example:

```
int i = 1;

while (i = 1)
    i++;
```

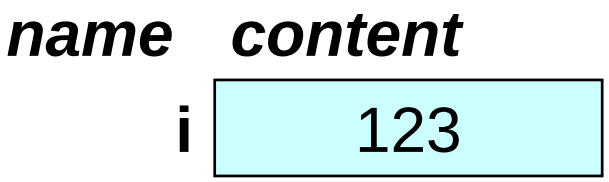
- Question:
  - How many iterations will you get from the while loop?

C Data Declaration

Terminology



Memory Box Diagram



Simple Data Types

```
int
unsigned int


char
unsigned char


float
double
```

- Integer data
  - Similar range to Java version
  - Unsigned version can store only non-negative values
- Character data
  - Unsigned version can store only non-negative values
- Floating point data

Simple Data Type : Comparison with Java

- Key differences to Java:
  - No object version
    - e.g. no built-in **`Integer`** class equivalence in C
  - **`char`** in C behaves like the **`byte`** datatype in Java:
    - To store small integer numbers
  - No initial value for variable

```
int i;   // i can be ANY value!!
```

Array

- A collection of **homogeneous** data
  - Data of the same type

```
int iA[10];
```

- Declaration: An array of 10 integers

```
iA[0] = 123;        Store value into 1st element

iA[9] = 456;        Store value into last, 10th element

iA[1] = iA[0] + iA[9];      Store and read values
```

Example Usage

Array in C: Comparison with Java

- Size of array must be given in declaration
- Array in C behaves like primitive datatype:
  - e.g. No need for "new int[10]"
  - No built-in methods (it is not a class!)
    - No way to check size
  - No automatic check for array bounds!
- Assignment is NOT allowed:

```
int ia[10], ib[10];
ia = ib;   //compilation error
```

- Behavior of Java array is actually closer to the pointer version in C (more later)

Structure

- A collection of **heterogeneous** data
  - Data of different type
  - Should be a collection describing a common entity

```
struct Person {
    char name[50];
    int age;
    char gender;
};

struct Person s1;
```

- Declaration: A structure to store information about a person:
  - **Name**: String of 50 characters
  - **Age**: integer
  - **Gender**: 'm' = male; 'f' = female
- **s1** is a structure variable

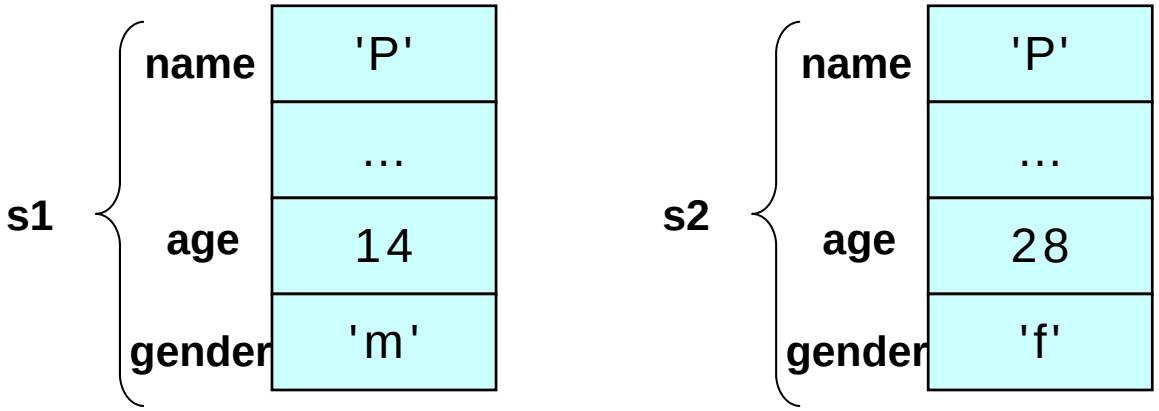
```
typedef struct {
... //same as above
} PERSON;

PERSON s1;
```

- Alternative declaration
  - Improve readability
  - Save some typing

Structure

```
PERSON s1 = { “Potter”, 13, ‘m’ };
PERSON s2;

s2 = s1;
s1.age = 14;
s2.age = s1.age * 2;
s2.gender = ‘f’;
```

Example Usage



Structure: Summary

- Assignment is possible:

```
struct Person s1, s2;
s1 = s2;   //s1 is a duplicate of s2
```

- Structure is the main way to organize information in C

- Similar to a class in Java with the following restrictions:
  - No methods declared
  - All attributes are public
  - Difference:
    - Statically allocated
    - e.g. No need for "**`new Person( )`**"

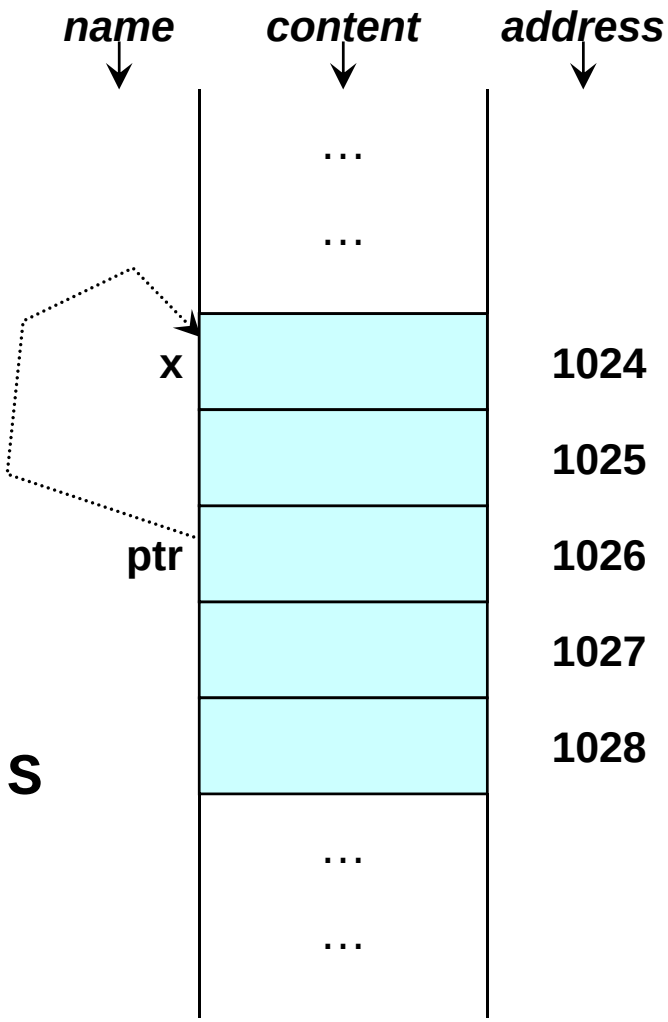
Pointers in C

- Memory is a one dimensional array:
  - Each memory location has an unique index
  - Known as memory address
- In Java, the memory address is hidden from the programmer
  - Stored in a ***Reference***
  - Handled automatically by the system
- In C, programmer has full control / access to memory address
  - Make use of ***Pointer*** variable for address manipulation

Pointer Variable

- A pointer contains the address of a memory location

```
int x;

int *ptr;        ptr is an int pointer

ptr = &x;        ptr points to x

*ptr = 123;      Dereference ptr
```



- **&** is the *Address-Of* operator
  - **&(S)** gives the memory address of **S**
- Note the different meanings of ***
  - Declaring a pointer
  - Deference a pointer

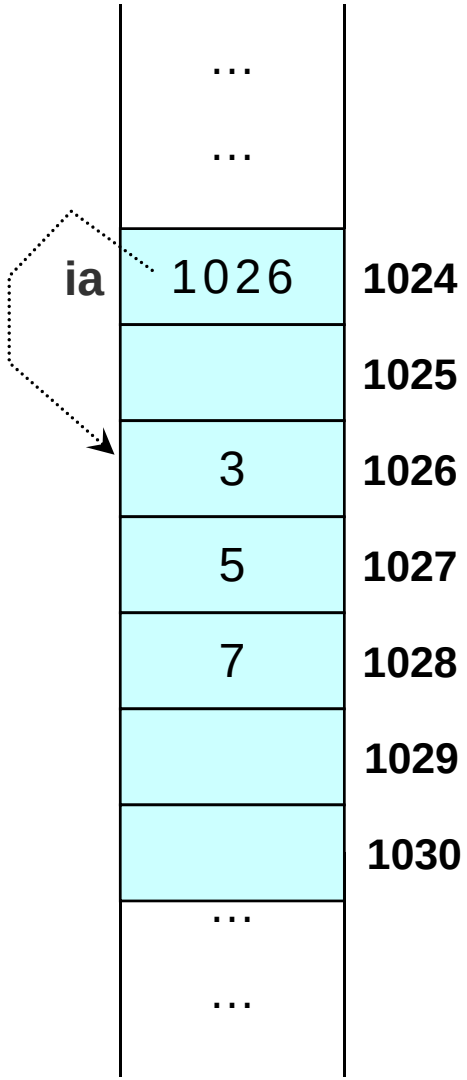
Pointers and Arrays

- Array name is a **constant pointer**
  - Points to the zeroth element

```
int ia[3] = {3, 5, 7};
```

- Is the following valid?

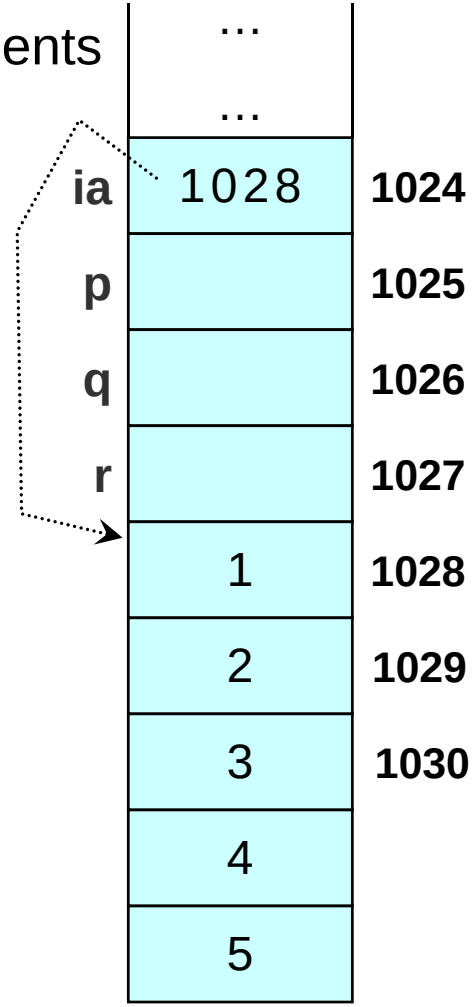
```
int* ptr;

ptr = ia;
ia = ptr;
ptr[2] = 9;

ptr = &ia[1];
ptr[1] = 11;
```



Pointer Arithmetic

- Addition and subtraction of pointers are valid
  - Pointer + *X* = Move **forward** *X* number of elements
  - Pointer - *X* = Move **backward** *X* number of elements

```
int ia[5] = {1, 2, 3, 4, 5};
int* p = ia;
int *q, *r;

q = p + 3;     //what is q?
r = q – 1;     //what is r?

//print   *p
//print   *q
//print   *r

//print   *p + 1
//print   *(p + 1)
```



Pointer Arithmetic

- Two forms of element access for arrays:
  - Using [ ], i.e. indexing
  - Using pointer arithmetic

```
int ia[5] = {1, 2, 3, 4, 5};

for (int i = 0; i < 5; i++)
      //make use of ia[ i ]
```

Using indexing

```
int ia[5] = {1, 2, 3, 4, 5};
int *ptr;

for (ptr = ia; ptr < ia + 5; ptr++)
      //make use of  *ptr
```

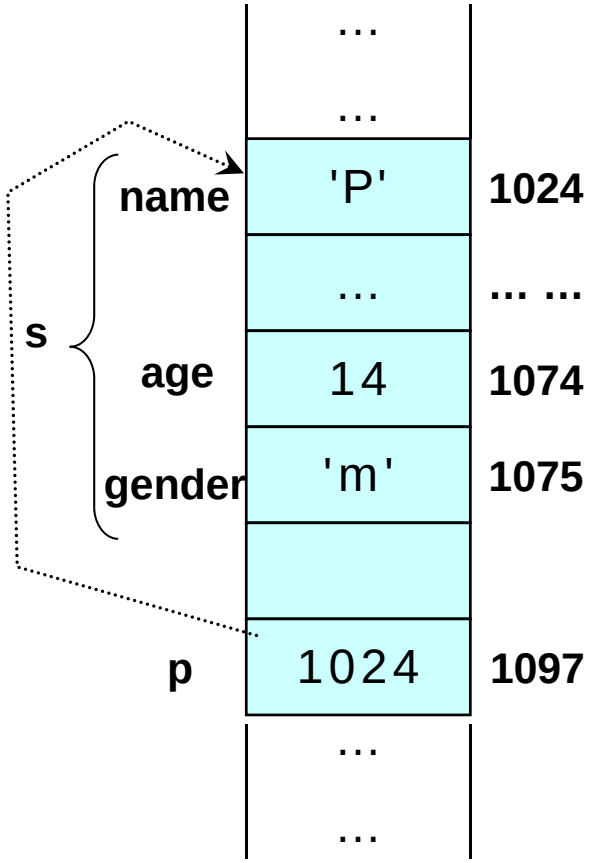
Using pointer arithmetic

Pointer and Structure

- Pointer can points to a structure as well

```
int main()
{
    PERSON s =
            { "Potter", 13, 'm' };

    PERSON *p; //Person Pointer


    p = &s;


    p->age = 14;

    (*p).age = 14;

}
```

Equivalent Statements



Dynamic Memory Allocation : `malloc`

- Up to now, pointers are used to point to existing (declared) variable
- Actually, new memory box can be allocated at **runtime**
  - Using the **`malloc()`** library call
- Header File:

```
#include <stdlib.h>
```

- Syntax:

```
malloc( size )
```

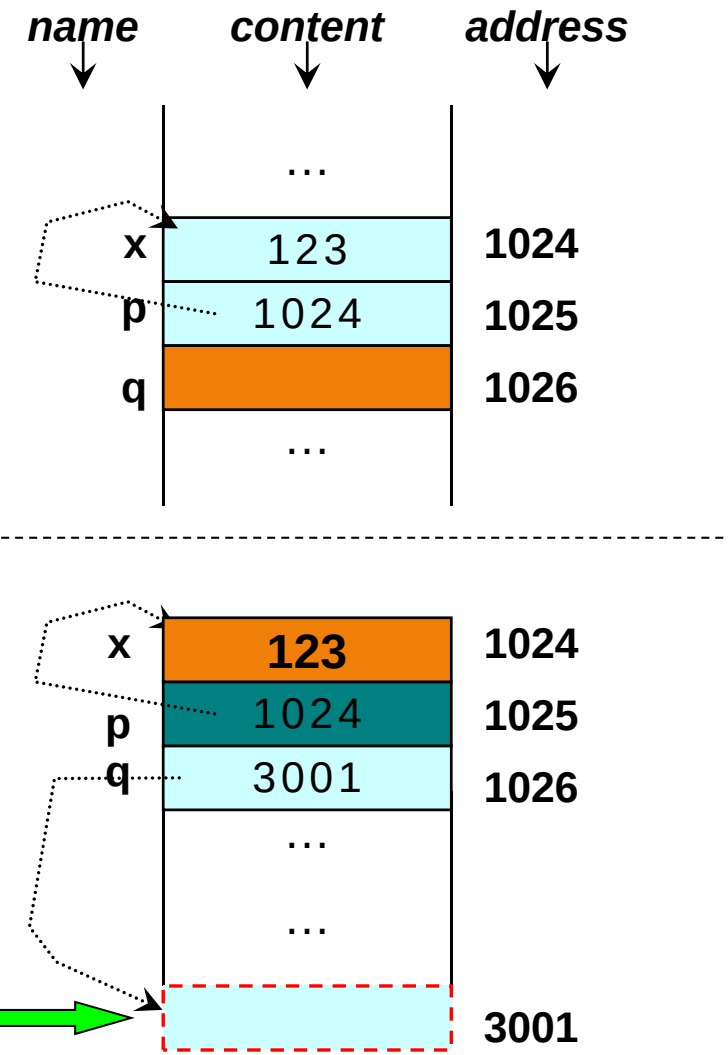
  where size is the number of memory bytes required
- **Address** of the newly allocated memory locations is returned by the function
  - Use pointer variables to store the address

`malloc` : Single Element – First try

```
int main()
{
    int x = 123;
    int *p, *q;

    p = &x;

    q = malloc( 4 );

}
```

At this point

At this point



`malloc` : Improvements

- The **`malloc( )`** function returns the address as a *datatype-less* pointer

```
void* malloc(...) ;
```

  - `void` ➔ no datatype
  - `void*` ➔ pointer that has no datatype
- Use type-casting to *convert* to the correct data type:
  - Example:

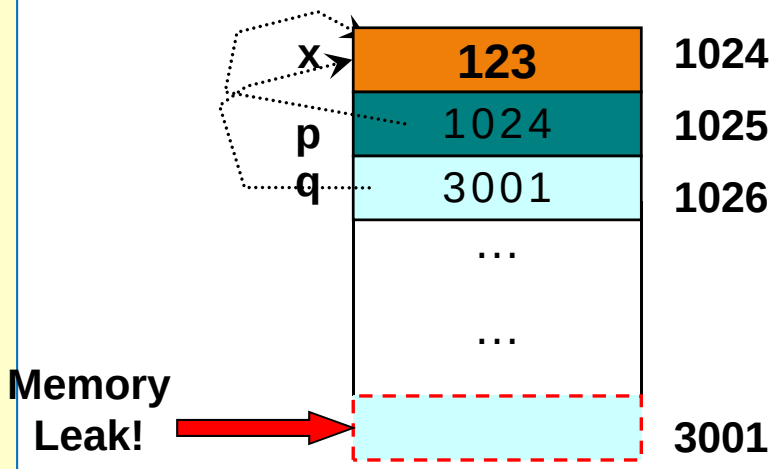
```
q = (int*) malloc ( 4 );
```
- Instead of memorizing the size of various datatype
  - Use **`sizeof()`** library call
  - Example:

```
q = (int*) malloc ( sizeof(int) );
```
  - Improve program portability

Memory Leak

- Important:
  - q is the **only** variable storing the address of the new memory locations
  - If q is changed, the new location is **lost** to your program, known as **memory leak**

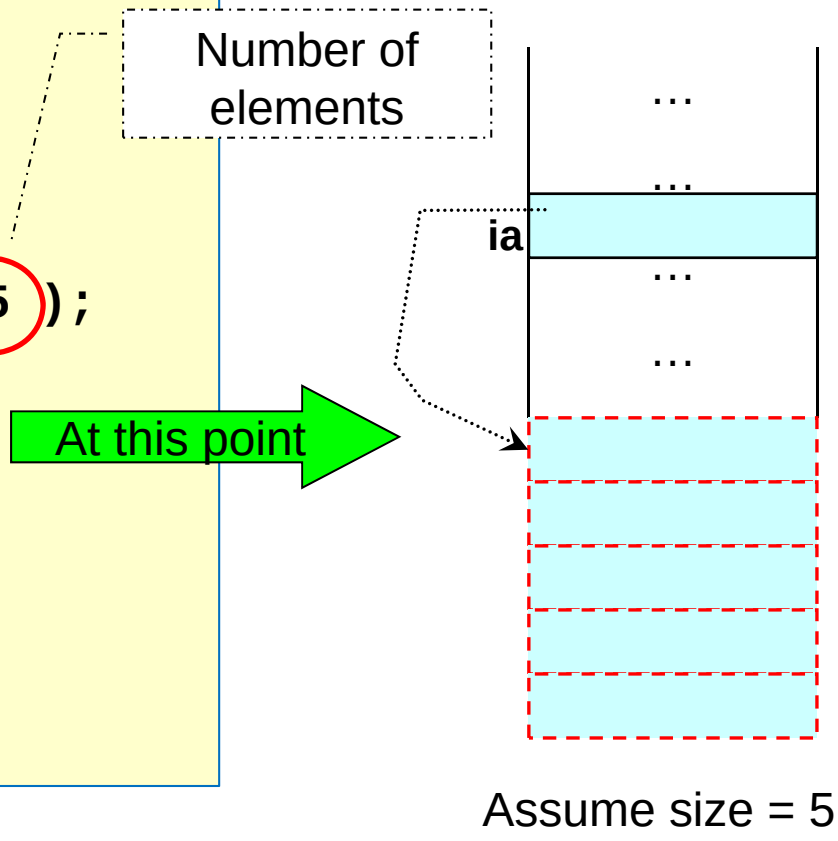
```
int main()
{
   int x = 123;
   int *p, *q;
   p = &x;

   q = (int*)
        malloc (sizeof(int));

   q = p;

}
```



`malloc` : Array of elements

- Whole array can be allocated dynamically
  - The size can be supplied at run time

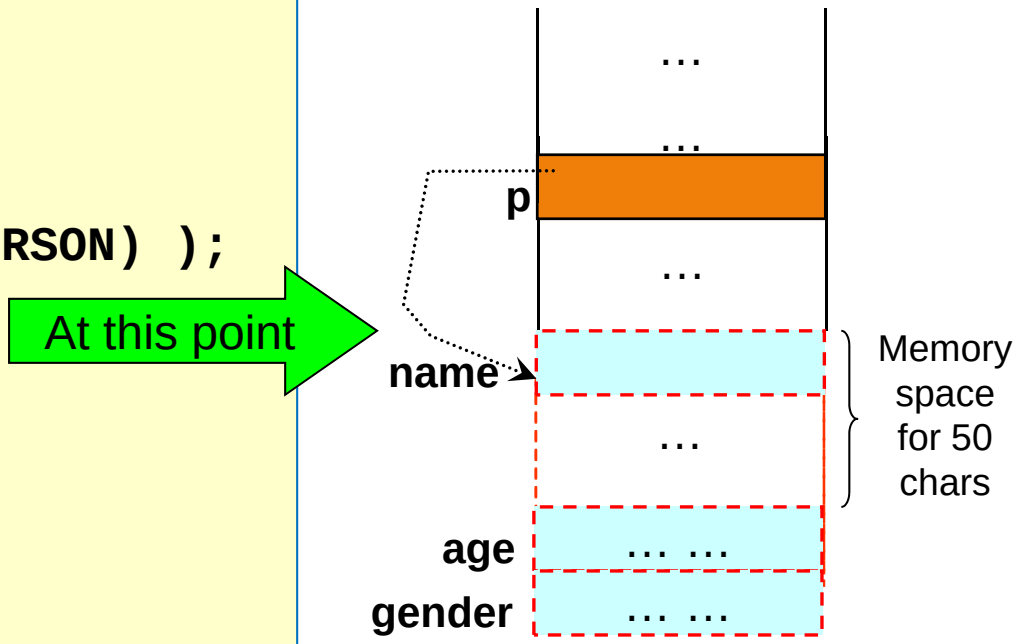
```
int main()
{
   int *ia;

   ia = (int*)
         malloc( sizeof(int)*5 );



   ia[0] = ...
   ia[1] = ...

}
```



`malloc` : Structure

- Dynamic allocation for structure is also possible

```
int main()
{
    PERSON *p;

    p = (PERSON*)
            malloc( sizeof(PERSON) );



    p->age = 14;

}
```



Releasing memory to system : **`free`**

- Dynamically allocated memory can be returned to the system (de-allocated)
  - Use **`free()`** library call
- Syntax:

  `free(`*`pointer`*`);`
- Memory location(s) pointed by *pointer* will be returned to the system
- Important:
  - Dereferencing pointer after ***free*** is invalid!

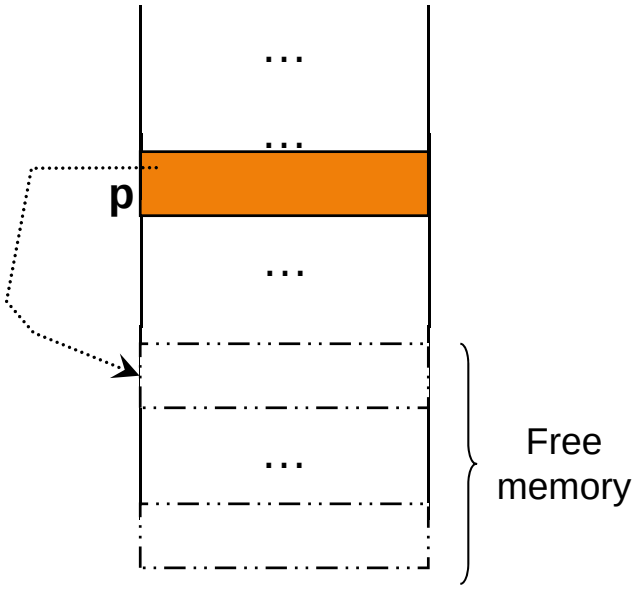
`free` : An example

```
int main()
{
   PERSON *p;

   p = (PERSON*)
          malloc( sizeof(PERSON) );


   p->age = 14;


   free(p);

   p = NULL;

   p->age = 14;

}
```

At this point

Good Practice: **Always** set a pointer to NULL after free

Error!



Pointer in C: Comparison with Java

- Pointer is similar to Reference in Java
  - In C:

```
PERSON *p = (PERSON*) malloc( sizeof( PERSON ) );
p->age = 30;
```

  - In Java (given a similar Person class):

```
Person p = new Person();
p.age = 30;        //assume age is public
```

- However, there is no need to clean up memory in Java:
  - Automatic Garbage Collection

C Function

Function in C

- Similar to a ***static method*** in Java
  - i.e. not associated with an object
- Syntax:

  return_type **function_name**(*parameters*)
- Example:

```
int factorial( int n )
{
    int result = 1, i;
    for (i = 2; i <= n; i++)
      result *= i;

    return result;
}
```

Function Prototype and Implementation

- Good practice to provide function prototypes

```
int factorial(int );

int main( )
{
   ...
}

int factorial(int n)
{
    int result = 1, i;
    for (i = 2; i <= n; i++)
      result *= i;

    return result;
}
```

Function prototype

Actual Implementation

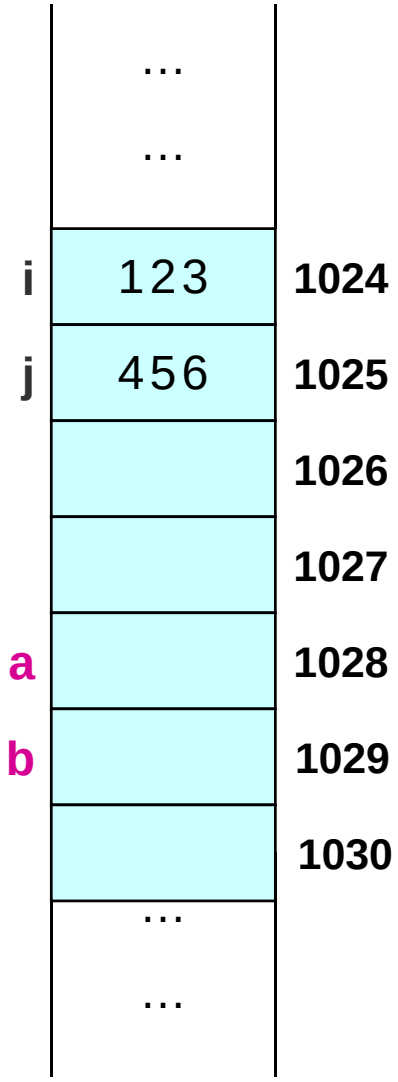
Function : Parameter Passing

- There are **two** ways of passing a parameter into a function:
  1. Pass by value
  2. Pass by address (Pass by pointer)

- Let us define a function **`swap(a, b)`** to swap the parameters
  - Using the two different parameter passing methods
  - Desired behavior: value of **`a`** and **`b`** swapped after function call

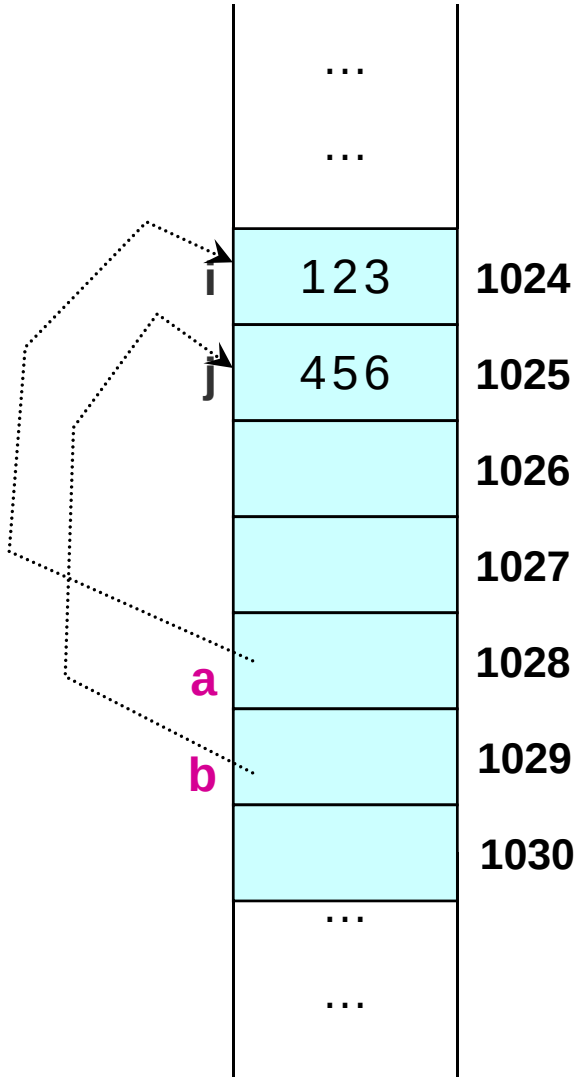
Function : Pass by value

```
void swap_ByValue( int a, int b )
{   int temp;

    temp = a;
    a = b;
    b = temp;
}

int main()
{   int i = 123, j = 456;

    swap_ByValue(i, j);

    //Print out i and j
}
```



Function : Pass by address/pointer

```
void swap_ByAdr( int* a, int* b )
{   int temp;

    temp = *a;
    *a = *b;
    *b = temp;
}

int main()
{   int i = 123, j = 456;

    swap_ByAdr(&i, &j);

    //Print out i and j
}
```



Function: Array as Parameter

- Array is passed by address

```
void f( int* a, int b[] )
{
    a[0] = b[0];
}

int main()
{   int iA[3] = {1, 2, 3};
    int ib[3] = {4, 5, 6};

    f( iA, iB);

    printf("%i", iA[0]);
}
```

Equivalent ways of specifying array parameter

Output is "4"

Function: Structure as Parameter

- Structure is passed by value

```
//Use the PERSON structure

void f( PERSON p )
{
    p.age = 55;
}

int main()
{   PERSON me = { "James", 12, 'm' };

    f( me );
    printf("%i", me.age);
}
```

Attempts to modify the age

Output is "12"

C Built-in Library

Built-in Libraries

- Similar to Java built-in packages:
  - C has built-in libraries
    - Provides common functionalities
    - Not as extensive as Java's
- To make use of a C Library:
  - Includes the respective header file:

    ```
    #include <XXXX.h>
    ```

  - Some libraries require special compilation command
- Impractical to cover everything in lecture
  - Introduce the essential and basic libraries only
  - Lab question will provide extra information

Standard Input/Ouput: **`stdio.h`**

- Header File:

  `#include <stdio.h>`

- Major functionalities:
  - Input – from keyboard, file
  - Output – to screen, file
- Output to screen:

  `printf( `*`format_string`*`, [data] );`
  - ***`format_string`***:
    - Specify format for data (if any)
    - Also with the plain message to be printed
    - Similar to **`System.out.printf( )`** in Java

Standard Output: **`printf( )`**

- Example:

```
int age = 55;
double income = 5432.10;
printf("Age is %i, Income is %f\n",age,income );
```

- Common format specifier:
  - `%i` : Print as integer
  - `%c` : Print as character
  - `%f` : Print as floating point
  - `%s` : Print as string
- Format modifier (Examples):
  - `%8i:` print integer with default width of 8
  - `%6.3f:` print floating point with default width of 6 with 3 digits precision

Standard Input: `scanf( )`

- Take input from standard input

  `scanf( format_string, [addresses] );`

  - *format_string* is similar to the printf's

- Important:
  - Supply the **address** of variable to store the input
  - Use the "&" operator if necessary

- Example:

```
int age;
scanf("%i", &age);  //note the "&"
```

Standard Input: `fgets( )`

- Reading string is slightly more troublesome:

```
char name[50];
scanf("%s", name);   //note the absence of "&"
```

  - Read only a **single word**
  - Reading ends as soon as a space is encountered

- Use **`fgets()`** to read a single sentence:

```
fgets( char* string, int size, FILE *stream);
```

- Example:

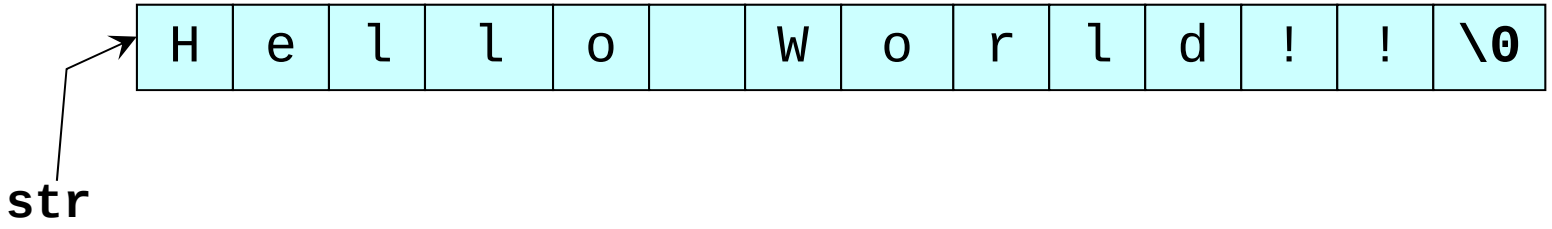
```
char name[50];
fgets(name, 50, stdin);
```

  - `stdin`: the standard input device

Character String in C

- String in C is represented as a *special* character array
- Example:

```
char str[14] = "Hello World!!";
```



- Note the `'\0'` at the end:
  - Known as the string terminator
  - Very important:
    - This is **only** distinction between a string and a simple character array in C

String Library : `string.h`

- Header File:

```
#include <string.h>
```

- Major functionalities:
  - Strings Comparison
  - Strings operation:
    - Duplicating a string
    - Strings concatenation
    - etc

String operations: Summary

- **`strcpy(char* dest, const char* source);`**
  - Copy the source to **`dest`** string
- **`strcat(char* dest, const char* source);`**
  - Add the source to the end of **`dest`** string
- Caution:
  - Make sure the **`dest`** string has enough space for the above functions

- **`int strcmp(char* s1, char* s2)`**

  Returns:
  - **`0: if s1 == s2`**
  - **`>0: if s1 > s2`**
  - **`<0: if s1 < s2`**

C Compilation

C: How to compile?

- C source code must have the extension ".c"
  - Example: **`helloWorld.c`**
- Steps for program compilation:

1. Edit program using your favorite editor (`vim`, `pico` etc)
2. Compile using the command:

   `gcc -Wall fileName.cpp` OR

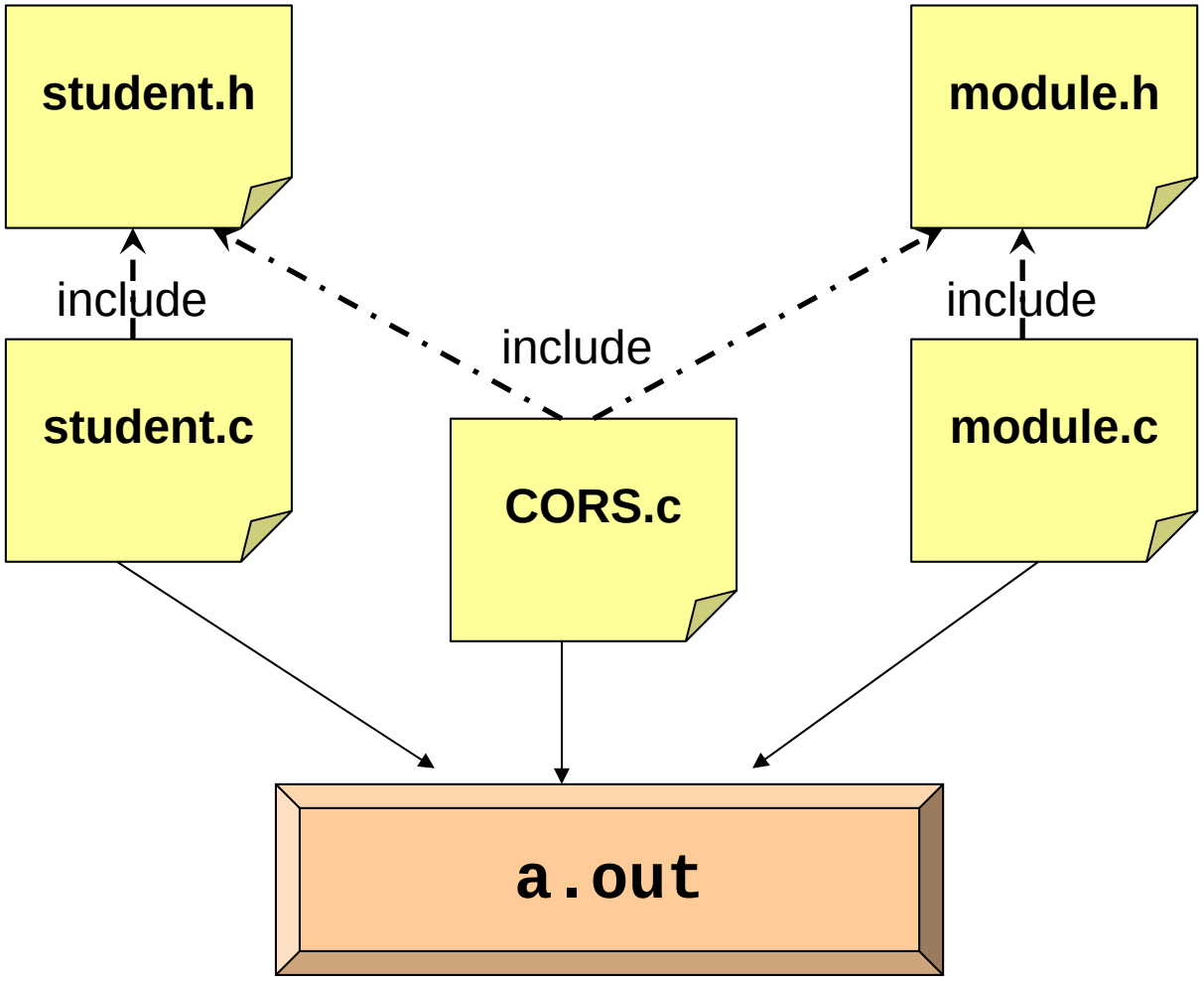
   `gcc -Wall –o executable_name fileName.cpp`
3. [Compilation Error]: Go to step 1
4. Execute the program:

   `a.out` OR ***`executable_name`***

Modular Design in C

- In Java, source code is organized into:
  - packages:
    - Contain a number of classes
- In C, source code ***can*** be organized into:
  - Header files (with extension ".h")
    - Contains declaration and function prototypes
  - Implementation files (with extension ".c")
    - Contains implementation of the function(s) declared
  - No enforcement
    - Programmer's responsibility to make use of it consistently

Modular Design: Example



Declartion + Prototypes

Actual implementation

Executable

C: How to compile multiple files

- Using the example from previous page:
  - **`gcc -Wall CORS.c student.c module.c`**
- The above ***recompiles*** every source code
  - Inefficient:
    - what if we have change only the CORS.c?
- Can compile individual source code:

  `gcc –Wall –c XXXX.c`
  - Produce **`XXXX.o`** if no error
  - Can selectively recompile
- To produce the executable
  - **`gcc –Wall CORS.o student.o module.o`**

Preprocessor: Macro

- A C source code is first preprocessed during compilation
- The preprocessor performs:
  - Textual substitution
  - Insert/Remove code
  - Locate and insert header file
- A command to preprocessor starts with "#"
  - Known as preprocessor ***directive***
  - Example:

    #include <stdio.h>
  - NOT part of C syntax technically

Preprocessor Directive: `#include`

- **`#include XXXX`**
  - locate and paste the file **`XXXX`** into the actual source code

- **`#include <XXXX.h>`**
  - **`XXXX.h`** is a standard C library
    - Store in a predefined location

- **`#include "XXXX.h"`**
  - **`XXXX.h`** is a file in local directory
  - User defined header file

Preprocessor Directive: `#define`

- **`#define X Y`**
  - locate occurrences of X in the source code and replace it by Y

- Example:

```
#define MAX 1024
int iA[ MAX ];
```

  - After preprocessing:

```
int iA[1024];
```

- A simple way to provide limited maintainability:
  - Just change **`MAX`** to a new value and recompile

Preprocessor Directive: `#ifdef`

- **`#ifdef X`**
  `... ... ... //Region A`
  `#endif`
- If **`X is`** defined earlier:
  - code in the Region A will be included in the compilation
- If **`X`** is not defined:
  - code in Region A will be removed
- Example:

```
#ifdef DEBUG
printf("Code for debugging\n");
...
#endif
```

- Can turn on debugging by:
  - Insert **`"#define DEBUG"`** before the fragment above